USABILITY REPORT

DATE: Aug 2, 2000

FROM: Ken Hinckley

RE: **TOUCHSCROLL KEYBOARD BIMANUAL SCROLLING CONCEPT**

EXECUTIVE SUMMARY

The TouchScroll Keyboard Bimanual Scrolling Concept study was conducted in three rounds on June 13-14, June 29-30, and July 20, 2000. This was initial informal testing and design iteration of a touch-sensitive scrolling strip integrated with the keyboard. Each round included 5 participants of intermediate to advanced computer skills, each group consisting of 3 women and 2 men. A greater proportion of women than men was included in the study because it was anticipated that more problems might arise with sensing women's fingers (long fingernails, hand lotions). The study included 3 left-handers (one in each round), although only one of these subjects used the mouse in the left hand (this subject was in the first round of 5 subjects).

Do users appreciate the product concept? What do users see as the major benefits (and drawbacks) of the scrolling strip?

All 15 users in the study responded well to the concept of a touch-sensitive scrolling strip integrated with the keyboard. In the final design tested, when asked if "The Scrolling Strip was an effective way for me to scroll through documents" the average response was 6.8, on a 1=Disagree to 7=Agree scale. The most frequent qualities that were reported among the "3 best things about the scrolling strip" were:

- *Less distance to move hands to scroll.* Users appreciated not having to reach for the mouse (or mouse wheel) to activate scrolling functions.
- *Alternative or Preferred to existing methods of scrolling*, *and overall Speed & Responsiveness.* Most users felt that the scrolling strip was quicker compared to using the mouse wheel or scroll bar. Users liked having an alternative on the keyboard. The strip also provides a nice balance of fine control and faster, coarser scrolling methods.
- *Using touch to control scrolling*. Users seem to like that a gentle touch without pressure activates the scrolling function.

On the other hand, when asked about the "3 WORST things about the scrolling strip," subject responses indicate potential areas for improvement:

- *Jumping feature*. A long-distance navigation feature via double-tapping was tested, but proved to be problematic.
- *Inappropriate length, width, or depth.* The present prototypes have not focused on the industrial design, and this needs to be improved.
- *Using the left hand to scroll*. Some users found the left hand strange to use at first but warmed up to it after a while. However, only 2 of the 15 users asked to move the strip to the right side instead of the left. All users were able to successfully use the prototype with their left hand.

Recommendations: The product concept is good and users can articulate why they like it better than existing solutions. Remove the jumping feature. The industrial design was neglected but is now getting more attention. Using the left hand to scroll was a new experience for users, but was not a source of significant usability problems in my view.

Can users discover how to use the scrolling strip?

All 15 users were at least able to use the basic scrolling function (sliding a finger in the main rectangular area of the strip) without any assistance. Almost all users were able to use the paging feature by tapping on the up and down arrows. A majority of users discovered the auto-scrolling feature, triggered by touching and holding the arrows, but several users did not. Only 5 of 15 users discovered that the arrows had a pressure-sensitive response, but this includes 3 out of 5 subjects with the final help panel design who *did* discover the pressure sensitivity on their own. Users felt that using pressure to control the rate of scrolling was natural to do.

All 10 users who tried the help panel as presently implemented could use it for initial guidance of how to use the strip, even if they largely ignored it.

Some users discovered the Jump (double-tap) feature on the main area of the strip and were able to use it successfully, but just as many triggered it by mistake and did not understand what it was happening. The double-tapping gesture of several subjects was recognized inconsistently or not at all.

Recommendations: The basic functions of the strip are discoverable. The help panel does seem to assist in initial discovery. The Jump (double-tap) feature causes more problems than it is worth.

What is the user's initial experience with our current "best guess" at the interface design and implementation?

Questionnaire items assessed each user's initial experience. Responses for most questionnaire items were higher in the final design iteration, suggesting that we were able to improve the overall design in almost all areas that were evaluated. For example, on the final question about the overall experience, the results were quite encouraging:

Round 1	Round 2	Round 3	Question (1=Disagree, 7=Agree)
5.8	6.0	**7.0**	12. Overall, the Scrolling Strip was easy for me to use.

Recommendations: The user's initial experience seems satisfactory, but some areas could still be improved. Future research should compare our prototype with the Synaptics implementation.

Can users employ the left hand to control scrolling functions? Do users like the concept of bimanual scrolling?

All users successfully employed the left hand to scroll the document. Several commented that it felt "weird" or "strange" to be using their left hand at first. Some users quickly realized that having the scroll function on the left side of

the keyboard would help to "free up" or "rest" their right hand. At least 2 subjects would have been happier to use their right hand to scroll.

Recommendations: Considering the novelty of using the left hand to control scrolling, there were surprisingly few problems or complaints about it, so the scroll function should be kept on the left. This usability study did not include tasks that required scrolling interleaved with pointing or clicking with the mouse, so such tasks should be included in future research to better assess the overall bimanual scrolling concept. Also, 3 left-handed and 1 ambidexterous subject were included in the sample; future research should look at acceptance by a sample of all right-handers.

Can users switch between scrolling on the keyboard, typing, and using the mouse without difficulty?

All users were able to successfully switch between typing and scrolling with few difficulties. One inefficient pattern that could be observed for all subjects, and was commented on by a majority of subjects, was the need to grab the mouse after scrolling *solely for the purpose of placing the insertion point* on the currently visible page. This requires the user to take their hands off the keyboard to click a single time, and then re-acquire the home keys.

Recommendation: The scrolling strip should support a gesture for placing the insertion point, or alternatively the insertion point should perhaps always remain at the same screen position as the user scrolls.

Are there any "missing features" of the scrolling strip which users will want or need to use it effectively?

Only two missing features were noted during the study:

1. Placing the insertion point, as noted above, was the most common observed oversight.
2. Two users asked about the lack of horizontal scrolling on Prototype A pictured above. I suspect more must have thought about it and simply not commented, because in Round 3, a test of a prototype with horizontal scrolling elicited several comments of this nature from users ("Oh, I had wondered how you could move left and right").

Recommendation: In addition to the insertion point issue, give serious consideration to a horizontal scrolling feature.

What should be the physical arrangement of functions and dimensions of the scrolling strip?

Recommendations: Based on the tests, my best guess would be 13.5mm wide, with a main area at least 35mm long (not including arrow regions), with soft tactile breaks between the arrows and the main strip, and with an inset depth of approximately 2mm. The up/down arrows (and left/right arrows, if any) should be approximately 13mm diameter. Place the strip higher on the keyboard with a better palm rest. Addition of an absolute or high-gain

scrolling feature should be seriously considered as a prototype including a dedicated region for this was favored by subjects.

What individual features of the scrolling strip software are most necessary or desired by users? How should the interface be designed and implemented to maximize user satisfaction? What is the impact of various design options and trade-offs on the user experience?

Recommendations: The main area is approachable and discoverable, widely accepted by users, and frequently used. *Stroking the main area should remain the most essential and critical function of the scrolling strip above all other features*. All 10 users asked to rank-order features rated this the most important. Specialized gestures on the main area of the strip may detract from the basic scrolling experience and should be very gravely considered.

For the basic scrolling action, support 1-Line increments by default if at all possible (scrolling in 3-Line increments has diminished value). Acceleration was well received and seems to help reduce repetitive stroking of the strip.

For the up/down arrows, single tap to page is a useful feature which is simple to use and understand. Combining auto-scroll with the page up/down feature also works well. Modulating the speed of auto-scrolling via finger contact area was also successful. *Do not implement any double-tapping feature on the arrows* because it interferes with Page Up / Page Down. Instead, try a control key combination like Ctrl + Tap Arrow.

Jumping is a powerful feature, but the double-tap gesture on the main area of the strip is *very risky* to the overall user acceptance of the scrolling strip. Users become very confused and annoyed when jumping happens by mistake. It is recommended to eliminate this function, turn it off by default, or provide similar functionality to this feature by another means (absolute mode).

Absolute Mode allows the user to move across the entire document when they slide their finger on the strip. Users liked this best when a separate area was dedicated to the function. Using the Alt or Shift key in combination with the main area of the scrolling strip is an alternative. Instead of an absolute mapping, a high gain factor should also be tried.

The Help Panel assists users in getting started with the strip. It was well received and seems to have contributed to users' positive initial experiences with the strip. It may not be appropriate for advanced users.

Sounds associated with the strip should be optional and off by default.

Bookmarking, to save positions in a frequently used document, was implemented but seemingly had little value for the end-user and the interface for it was a total failure.

FINDINGS AND RECOMMENDATIONS

Do users appreciate the product concept? What do users see as the major benefits (and drawbacks) of the scrolling strip?

A more complete characterization of user responses, when asked to describe the "3 **BEST** things about the scrolling strip", follows. There were 41 total responses from 15 total subjects:

- *Less distance to move hands to scroll [9].* Example: "I don't have to reach for the mouse. It's right there at the keyboard."
- *Alternative or Preferred to existing methods [6].* Example: "Less work – scrolls quicker compared to wheel or scrollbar. Seems faster."
- *Speed & responsiveness [6].* Example: "Scrolling smoother. You have fine control and fast motion too. A nice balance of fine vs. fast motion."
- *Using touch to control scrolling [6].* Example: "I liked the touch of it – it's easy, and no pressure is required."
- *Seems familiar or easy to use [3].* Example: "I liked the middle part and how easy it was to move."
- *A particular feature that an individual user really liked [7]:*
    - Paging by tapping on arrows [3].
    - Jumping by double tapping [2].
    - Pressure sensitive arrows [1].
    - Help triggered by touching the strip [1]
- *Details of the industrial design [2].* Examples*:*
    - Concave – you make contact with it only when you want it [1].
    - The resting area [blank area to left of the scrolling strip] [1].
- *Using the left hand [2].* Example: "I like the position of it – it frees up my right hand."

This is a complete list of the "3 **WORST** things about the scrolling strip" reported by subjects. There were 38 total responses from 15 total subjects:

- *Jumping feature [6].* Example: "Too sensitive. I'd want to adjust that." The various implementations I tried varied in quality, but in general double-tapping on the main area of the strip to jump seems problematic. It is a powerful way to move long distances quickly, but it is risky because users become very confused when it is triggered by mistake. The gesture also lacks precision, and is not always recognized when performed, so users may have difficulty jumping to a specific area of a document.
- *Inappropriate length, width, or depth [6]:*
    - Width too narrow and/or arrows too small [3].
    - Too deep [2]. Example*:* "Groove is nice, but maybe not so deep?"
    - Length too short [1]: Example: "I want to move my finger farther."

- *Using the left hand to scroll [5]:*
    - Left side strange *at first* [2]. Example: "Having left hand do it is a little odd at first, it didn't seem useful to do it that way until I got into using it a little more."
    - Put it on the right. [2]. Example: "It would be better on right side."
    - Put one on both sides of keyboard [1].
- *Missing Features [4]*
    - Placing the insertion point. [2] Example: "Needs Right Click, Single click to place keyboard focus in input areas."
    - Lack of horizontal scroll [2]. Example: "How do I move left and right?"
- *Sounds (audio feedback) [3].* Example: **"**Turn the sound off maybe?"
- *Fatigue [2].* Example: "A little tiring." (N.B: Several other users complained of some fatigue due to lack of wrist support, but did not mention it as a "worst thing," so I believe this may be a more significant problem with the current prototype than this sample suggests.)
- *Difficulty encountered using or understanding other features [7].*
    - General complexity [1]: "A little getting used to but not so bad."
    - Auto-scrolling [2].
        - Unsure how much pressure to use for auto-scrolling. [1]
        - Slight delay before auto-scrolling "not all that irritating." [1]
    - Tapping arrows not working [4]. 2 bugs causing this were fixed.
- *Other details of the industrial design [4]:*
    - Keyboard too big [1]. Example: "Will it fit in my keyboard tray?"
    - Switching between devices with mixed typing & scrolling [1]. (This was a left-handed user who disliked switching between the mouse in the left hand, and the strip on the left side.)
    - Placement of arrows [1]. Wanted to rest fingers on both arrows at once. This may not be feasible because current commercial touchpads cannot detect simultaneous contact at 2 different points.
    - No palm rest [1]. "Resting encourages bad typing posture. Don't have a rest spot." (N.B: Several users instead asked for a better / larger rest area.)
- *Benevolent User [1].* Example: "No big dislikes."

Can users discover how to use the scrolling strip?

Subjects were told the keyboard had "a new feature for scrolling" but were not told anything about how to use it. The location of the strip was pointed out to them, and they were asked not to use scrolling keys (arrows, page up/ page down, etc.), the mouse wheel, or the graphical scroll bar, so that the test could focus on the new method rather than existing ones. All subjects were given "Prototype A," a straight Microsoft Internet Keyboard modified

with a left pod (Fig. 1), for the initial experience with the scrolling strip. Subjects were told to ignore the buttons above the scrolling strip; these buttons were not used or enabled at any time during the study.

Fig. 1. Prototype A of the scrolling strip on the left pod of the Microsoft Internet Keyboard. (N.B: The shape of the strip differed slightly in Rounds 1 and 2.)

All 15 users were at least able to use the basic scrolling function (sliding a finger in the main rectangular area of the strip) without any assistance. Almost all users were able to use the paging feature by tapping on the up and down arrows with the exception of 4 users in the first and second rounds of the study who encountered some bugs with this feature (both bugs were fixed). A majority of users discovered the auto-scrolling feature, triggered by touching and holding the arrows, but several users did not.

In the first round of the study, only 1 of 5 subjects was able to use the help feature. All of the remaining 10 subjects in the last 2 rounds were able to use the help panel without assistance, after several design revisions were implemented (See *Help Panel* for details.)

Most users did not discover that the arrows had a pressure-sensitive response; only 1 subject in each of rounds 1 and 2 of the study noticed this, but 3 out of 5 subjects in round 3 did discover the pressure sensitivity on their own (the help feature had been improved and a comment about the pressure sensitivity was added to the help panel).

Some users discovered the Jump (double-tap) feature and were able to use it successfully, but just as many triggered it by mistake and did not understand what it was happening. The double-tapping gesture of several subjects was recognized inconsistently or not at all.

Fig. 2 summarizes the features found by individual users.

Ss	Main Area (touch & slide to scroll)	Tap to Page Up/Page Down	Hold to Auto-scroll	Pressure to change Auto-scroll rate	Double-Tap to Jump (main area)	Help panel
Round 1						
1	Y	Y	no	no	Y	no
2	Y	Y	Y	Y	no	no
3	Y	Y	Y	no	no	Y
4	Y	no	no	no	Y	no
5	Y	no	Y	no	Y	no
Round 2						
1	Y	Y	Y	no	Y	Y
2	Y	Y	Y	no	Y	Y
3	Y	Y	no	no	Y	Y
4	Y	Y	Y	Y	no	Y
5	Y	Y	no	no	no	Y
Round 3						
1	Y	Y	Y	no	Y	Y
2	Y	Y	Y	Y	Y	Y
3	Y	Y	Y	Y	no	Y
4	Y	Y	Y	no	Y	Y
5	y	Y	Y	Y	no	Y
∑	**15**	**13**	**11**	**5**	**9**	**11**

Fig. 2. Features discovered by users during initial experience.

What is the user's initial experience with our current "best guess" at the interface design and implementation?

User responses to the questionnaire items were used to track overall response to a number of dimensions of our "current best guesses" at the user interface design, industrial design, and implementation for each Round of the study. Responses for 8 out of the 12 questionnaire items were higher in the final design iteration (Round 3, bolded) than in Phase 1. However, the audio feedback feature (question 10) was a conspicuous failure in this regard, where ratings declined in every single round. Fig. 3 shows the full list of questions:

Round 1	Round 2	Round 3	Question (1=Disagree, 7=Agree)
6.0	6.2	**6.8**	1. The Scrolling Strip was an effective way for me to scroll through documents.
1.6	3.6	**2.2**	2. The speed at which the document scrolled was too fast.
4.6	6.6	**2.8**	3. When I touched some part of the Scrolling Strip, it sometimes caused an action that I didn't intend.
3.8	4.4	**2.8**	4. It was awkward to use my left hand to control the Scrolling Strip.
4.0	6.4	**6.0**	5. It was obvious to me how to use the Scrolling Strip.
--	4.6	**6.2**	6. The Help for the scrolling strip assisted me in discovering how to use it effectively.
3.4	3.8	**3.8**	7. What do you think about the LENGTH of the Scrolling Strip? (Too Short=1, Too Long=7)
3.4	3.0	**3.8**	8. What do you think about the WIDTH of the Scrolling Strip? (Too Short=1, Too Long=7)
--	3.2	**3.2**	9. What do you think about the size of the Up / Down arrows? (Too Small=1, Too Big=7)
3.2	2.2	**1.2**	10. The sounds that the program made while I was scrolling were helpful to me.
6.0	2.4	**5.0**	11. I liked using both hands to operate the computer while scrolling[1].
5.8	6.0	**7.0**	12. Overall, the Scrolling Strip was easy for me to use.

Fig. 3. Questionnaire items for the user's initial experience with the strip.

Can users employ the left hand to control scrolling functions? Do users like the concept of bimanual scrolling?

While all subjects could use the left hand, the study included 3 people who were left handed, only 1 of which actually used the mouse in his left hand. One other subject also claimed to be ambidexterous. Potentially, this could have biased the response in favor of placing scrolling on the left. Two of these left-handers were intentionally recruited so that we would have some data on left-handed users. Unfortunately, the subject screening questions were not specific enough and some of the other "right handers" proved not to be.

[1] This question was observed to confuse many users, so it is not clear what the responses may indicate. The average response differs widely, but seemingly doesn't correlate to any feature that was changed.

What should be the physical arrangement of functions and dimensions of the scrolling strip?

Initial design

An initial design for the scrolling strip (prototype A, Fig. 1) was evolved in Rounds 1 and 2. The radius of the curved bezel leading to the strip surface was truncated with a short wall; if it leads smoothly down to the surface, the user's finger has a tendency to ride up out of the groove, and thus can lose contact with the surface.

Overall users reported that the main area of the strip was not wide enough ("What do you think about the WIDTH of the Scrolling Strip? (An answer of 4, in the middle, means 'Just Right')"; average response 3.4 across 15 users). It was also felt to be slightly too short (average response 3.8 on a similar question). Some users had difficulty getting their fingers into the (initially) very narrow strip and arrow regions. Although not explicitly asked, many users commented that the groove was too deep and that it was placed too low on the keyboard (or similarly, that there was not enough palm rest below it).

The strip was widened and the radius of the up/down arrow regions was increased. The touchpad technology also works better when there is firm contact across a wider area. Finally, the depth of the groove in prototype A was increased to about 4mm, because of a technical problem with the hand being sensed through the keyboard case. This is definitely too deep. Fortunately, Steve Bathiche discovered this problem can be eliminated by placing copper tape, conductive face up, underneath the bezel, and connecting it to the touchpad's ground.

Other variations of the scrolling strip layout

To gain some additional insight into desired length, width, placement, and overall layout of the strip, in Round 3 several different treatments of the scrolling strip were presented to test users.

These included prototype A (Fig. 1) as well as prototypes B, C, and D pictured below.

Prototype A (Fig. 1): This prototype was the first one that all users tried. The main area is 8.5mm wide and 35mm long. The up and down arrows have a 14mm radius, but are truncated where they meet the main area (reaching a maximum of 11.5mm high). The bars separating the arrows and the main area are 2mm thick and about 2mm high. The strip is sunk approximately 4mm into the keyboard case.

Several women with even moderate-length fingernails had difficulty making effective contact with the strip. This sometimes led to compensating strategies such as using a different finger, holding the finger more flat on the strip, or simply not using a certain feature (e.g. the up arrow). Several men with large fingers felt that the groove was confining. Some users felt the strip was a little to short. Not even one user – including all 15 subjects in all 3 rounds in this case – asked for it to be shorter.

Recommendations: This strip is too narrow. The groove is also too deep; the steep profile of the groove edges also influences this. The strip may be slightly too short, but the current length does not seem to result in significant usability problems. Try placing the strip higher on the keyboard with a better palm rest.

Prototype B (Fig. 4): This prototype tested a minimal design. It is 13.5mm wide, and a total of 62mm long. The active area of the up and down arrows, however, is about 10mm each, making the main area approximately 42mm long. Time did not permit construction of a full keyboard prototype, so this treatment was presented on a stand-alone touchpad which was placed at the left edge of the keyboard incorporating prototype A. The touchpad was secured in place with an adhesive compound similar to chewing gum.

Users liked the overall larger dimensions of this pad, but the lack of any dividers at all between the main area and the arrows was poorly received. All users activated a function by accident at least once, or verbally stated that they were *worried* they would hit something by mistake.

Fig. 4. Prototype B, a scrolling strip without arrow separations.

Recommendations: The 13.5mm width tested well and would be a good default value for future designs. Designs of the strip which lack a divider (whether provided by the keyboard bezel, or as a tactile cue on the surface of the strip itself) negatively impact usability and are strongly discouraged.

Avg. Rating	Question
6.4	Assuming both were integrated with the keyboard in a similar manner, I would rather use prototype B than prototype A.
5.2	I felt I was more likely to make a mistake with prototype B.

Fig. 5. Questionnaire items related to Prototype B (5 total users).

Prototype C (Fig. 6): This prototype provides a basic horizontal scrolling feature. The prototype was constructed by hand, again on a stand-alone touchpad, due to time constraints. The left/right arrows were approximately 13mm wide and 15mm high. Tapping on the arrows moved the document left or right in increments of 44 pixels (the same as 1 notch of the wheel with the

3 lines per detent setting). Holding on the arrows provided pressure-sensitive auto-scrolling.

Fig. 6. Prototype C, a scrolling strip with horizontal arrows

The prototype was successful in providing a horizontal scrolling feature that users could easily understand. User experience with the left/right arrows was very similar to the up/down arrows (see *Up and Down Arrows* for details).

The distance moved with a single tap probably is not far enough; as one user stated, "I have wide spreadsheets, that would take all day." One user wanted to move diagonally, and was disappointed that this was not possible (by holding two arrows at once). This is not technically feasible on the Synaptics touchpad.

Avg. Rating	Question
6.4	It was easy to use the horizontal scrolling arrows.
5.2	The horizontal scrolling feature that I tried today would be useful to me in my typical applications.
3.0	What did you think of the distance that the document moved left or right in response to a single tap? (Moved Too Little=1, Moved Too Much=7).
4.2	When I held still on the horizontal arrows, the speed of the continuous horizontal scrolling was: (Too Slow=1, Too Fast=7)
5.4	If the scrolling strip did NOT include a horizontal scrolling feature, then I would be less likely to purchase it.

Fig. 7. Questionnaire items related to horizontal scrolling (5 total users).

Recommendations: Although the horizontal scrolling feature is simplistic, it seemed to largely satisfy users to have at least *some* way of achieving this. Consider increasing the distance moved by a single tap a little bit.

Prototype D (Fig. 8): The main purpose of this prototype was to explore placement of a scrolling strip at the center of a natural keyboard. By

necessity, this prototype also used a smaller touchpad than the others, so it also presented an opportunity to test a strip with smaller dimensions. The main area of the strip is 13.5mm wide by 23mm high. To compensate for the short length, the software gain of the scrolling strip was adjusted to provide a response that was approximately equivalent to the other prototypes. The up/down arrow regions are each 10mm high, including the white spacer (actually a 2mm thick strip from a vinyl lettering kit).

A variant of prototype D (*Fig. 8*, right) was also constructed. Prior to user testing, this version was rejected because the strip was too low, resulting in flexion of the wrist to reach it with the index finger of the left hand, and it was also felt that it lay at an awkward angle to use it.

Prototype D provides one feature not implemented on the others, which is an absolute mode provided by the blank area at the right of the pad. This function is described in further detail below (see *Absolute Mode* below). The sawtooth area is 10mm wide.

Fig. 8. Left: Prototype D. Right: An earlier version of Prototype D.

Of the 5 users who tried Prototype D, three normally used straight keyboards, and two normally used natural keyboards.

Only 1 of the 5 users, a straight keyboard user, liked the strip placement near the center of the keyboard (average response to "I preferred having the scrolling strip near the middle of the keyboard" was 2.8, disagree). Several users felt that they had to avoid hitting keys by mistake while using it, compared to placement on the left side. It was also associated with pointing solutions (regular touchpads, trackpoint, etc.) when placed here.

Users also definitely felt that this length was too short (on a 1…7, too short…too long scale, the average response was 2.2). One user had difficulty employing the up arrow because of its small size.

Prototype D was also the only prototype that used low-profile vinyl strips to provide separations between the arrows and the main area of the strip. This separation not only seemed adequate, but several users preferred the "softer breaks."

Recommendations: Placement of a strip near the center of the keyboard seems to be undesirable, but should be tested with additional natural keyboard users since only 2 such users were in this study. The small size of this scrolling strip negatively impacts usability. But the increased width, soft tactile breaks for the arrows, and particularly the sawtooth function lead users to rate it highly overall (see below).

Subject Rank-Orderings of Prototypes A, B, C, D: Subjects were asked to rank-order the prototypes, and explain the reasons for their assigned order. Four out of the 5 subjects ranked prototype D first, and all of these subjects mentioned the sawtooth (absolute mode) feature as one of their reasons for doing so. Average and individual rankings are shown in Fig. 9 and Fig. 10.

Avg. Rank	Prototype	Why? [How many Ss]
1.6	D	Liked sawtooth feature [4], soft breaks [2], placement in middle [1], wider [1], less deep [1]. Disliked shortness [3], placement in middle [3], arrows hard to hit [1], sawtooth feature [1].
2.2	C	Liked ability to horizontal scroll [5]. Disliked sensitivity (gain set too high) [2], single tap on left/right arrows doesn't go far enough [1], inability to rest on both arrows [1].
3.0	A	<This one was the default first experience.> Liked separation of the arrows. Disliked: Too narrow, too deep, breaks too hard (get in the way).
3.2	B	Liked wider [4], longer [2], less deep [2]. Disliked: lack of dividers for arrows [4], hitting the wrong thing [3], have to look at it [1].

Fig. 9. Average rank of prototypes and reasons why.

Prototype	1st	2nd	3rd	4th
A	0	0	5	0
B	0	2	0	3
C	1	3	0	1
D	4	0	0	1

Fig. 10. Number of votes which each prototype received for rank ordering.

What individual features of the scrolling strip software are most necessary or desired by users? How should the interface be designed and implemented to maximize user satisfaction? What is the impact of various design options and trade-offs on the user experience?

Basic Scrolling

This refers the fundamental function of touching the strip and sliding one's finger to scroll. This main area was very intuitive for users, and most users started using the strip by touching or stroking this area. The main area was primarily used to cover short distances, and other features (paging,

autoscrolling, or jumping) were generally used to cover long distances, although at least 1 subject used the main area to do virtually everything. *It was the only feature of the scrolling strip that every single user seemed to grasp right away*[2].

The exact style of usage differed very widely. Some users would touch very lightly with their index finger and slide their finger slowly across the strip. Others preferred to dab at it in short stroking motions (almost like a tap) to nudge the scrolling along bit by bit. Still other users would tend to zip their finger along very quickly, much like an experienced wheel user would fling it around. Some (especially women with long fingernails) tended to hold their finger very flat on the strip, so that the entire pad of the finger rested on it.

Some users employed the middle finger to operate the main area. Two users were observed to stroke it with their little finger, but this was only done when they began tasks that involved mixed typing and scrolling. One user operated it with her thumb because the fingernails on her other fingers got in the way.

Only one user tried to initially operate it with his right hand. After noting this, I asked him to use his left hand instead since that was the concept we wanted to test for this product.

It should be emphasized that *the wide variety of usage patterns exhibited by subjects makes it difficult, on the main area of the strip, to support gestures* such as flicking, tapping or double-tapping, or modes initiated by changes in contact area. All of these gestures, depending on the individual user, may look very similar to the normal motions the user makes to scroll the document. As such all of these gestures are prone to both false-positive and false-negative recognition errors, and if they are supported at all, the consequences of recognition errors should be minimized.

Recommendations: The main area is approachable and discoverable, widely accepted by users, and frequently used. Based on this, *stroking the main area should remain the most essential and critical function of the scrolling strip above all other features*. Other features, such as specialized gestures on the main area of the strip, may detract from the basic scrolling experience and should be very gravely considered. In terms of the initial user experience, *the main area **is** the scrolling strip, and it is very important not to interfere with this by adding bells and whistles.*

Design Options:

Line scrolling, 1 line vs. 3 lines per notch: This comparison was made only in Rounds 1 and 2. 9 out of 10 users preferred one line increments to three line increments. Several users thought they had to press harder to scroll with the 3 line setting. Typical comments were that it felt "sticky" and reminded users of the response when using the mouse wheel (and they didn't like this). Only 4 out of 10 users thought the scrolling strip would still be an appealing product if it worked this way. When asked to quantify this, however, it seems that most users did not feel particularly strongly about this issue ("The Scrolling Strip would be an appealing product to me if it scrolled 3 lines at a time"; average response 3.6 (disagree), where a 4.0 would be neutral).

Recommendation: Support 1-Line increments by default if at all possible. If

[2] Some users did start by paging or autoscrolling, but when they tried the main area they immediately seemed to understand what to do.

the product can only scroll in 3-Line increments like the IntelliMouse wheel, the scrolling strip has diminished value and users will be less likely to employ it for scrolling. But by the same token, it seems that many users will still find it useful if this is necessary.

With and without acceleration (speed-sensitive response): This comparison was made only in Rounds 2 and 3. In Round 2, three out of five users preferred acceleration. In Round 3, the gain and acceleration factor were adjusted to be less sensitive, and all five users preferred acceleration in this case. A potential problem with acceleration, not observed in this study, is that the user may not return to the same point in the document if they slide their finger, and then return to the same position on the strip. This does happen if the user moves sufficiently fast, but was not remarked upon by test users—so it is unclear if this really is a problem from the user acceptance perspective.

Round	"I prefer the strip when it has a speed-sensitive response (as opposed to always moving the same amount)."
2	4.0
3	6.2 : Improved when acceleration set to be less sensitive.

Recommendations: Users preferred acceleration in this study, so present data suggests it should be supported. However acceptance of the feature seems fairly sensitive to the setting (too much acceleration causes loss of control, as seen in Round 2). The possible problem of returning to the same position again should be investigated further.

Pixel-by-pixel scrolling or line-by-line scrolling: The result was unclear. Many users had difficult telling the difference between these two. The implementation of pixel-by-pixel scrolling in the present prototype suffers from redraw problems, which makes the text appear fuzzy or unfocused. Users were evenly split on which was preferred (7 pixel-by-pixel, 7 line-by-line, 1 user "didn't care").

Recommendation: Although this issue cannot be resolved with the current prototype, this does not seem to be a critical feature of the scrolling strip, although our experience with multiple iterations of the prototype seems to support a general preference for smooth scrolling.

Relative Priority of Features

To compare the relative importance of some of the proposed features, in Round 1 and Round 2 users were asked to rank-order the features they had tried (Fig. 11). *All 10 users ranked the basic scrolling function (sliding one's finger on the strip) as the most important feature*, further supporting the conclusion that this is the core feature for users. This rank-ordering exercise was done at the very end of the study after the users had tried all features and options being tested.

Round 1	Round 2		Feature
Avg. Rank	**Avg. Rank**	**Appeal** 1=Must Not Have 7=Must Have	
1.0	**1.0**	6.8	Touch & slide finger to scroll view
2.25	**3.0**	6	Paging up and down using the Up / Down arrows
--	**3.8**	5.8	Speed-sensitive scrolling response based on how fast you slide your finger on the main area of the strip
4.5	**3.8**	5.4	Auto-scrolling by touching and holding the up/down arrows
3.67	**5.6**	4.4	Jumping
4.75	**5.8**	3.8	Pixel-by-pixel scrolling (as opposed to line-by-line scrolling)
6.33	**--**	--	Rapid Scanning (via double-tap-and-slide)
6.75	**6.4**	4.6	Having Help for the scrolling strip based on touching or holding your finger on the strip
6.75	**--**	--	Bookmarking (Adding Bookmarks and Jumping to Bookmarks using the bookmarking panel)
7.25	**6.6**	3.2	Audio feedback when you do something on the strip

Fig. 11. Subject rank-ordering of features in Round 1 and Round 2.

Up and Down Arrows

***Tap to Page Up / Page Down**:* Next to sliding one's finger in the main area of the strip, this was probably the next most used and easily understood feature of the scrolling strip. Some bugs were discovered and fixed with this feature during rounds 1 and 2, which tended to lower the overall ratings of the feature a bit ("I liked moving through single pages (Page Up and Page Down) with the Up / Down Arrows", average response 6.0 and 6.6 in Rounds 1 and 2, respectively).

Recommendation: This is a useful feature which is simple to use and understand. One usability problem remains: if the user is too deliberate about tapping on the arrow, it may not be recognized, because the auto-scrolling timeout is slightly too short now. It is currently set at 500 ms and should be increased to 700 ms (the setting used in Round 2, where this problem was not observed to occur).

Hold to auto-scroll: Although not quite as easy to discover as the tap to page, auto-scrolling was also perceived to be a useful feature ("Auto-scrolling by holding on the Up / Down Arrows is a useful feature to me," average response 6.4 and 6.6 in Rounds 1 and 2). A few users commented that "auto-scrolling" was too technical a term and this feature should be called something else. Some users noticed the time-out before auto-scrolling begins and wondered why it was there, or found it slightly irritating.

Recommendation: Combining auto-scroll with the page up/down feature works well. Although users sometimes noticed the delay necessary to separate tapping from holding (for auto-scrolling), *do not shorten or remove this delay*, because doing so makes it very difficult for users to use the page up / page down feature without error.

***Pressure Sensitive auto-scroll*:** This extension to auto-scrolling was well received and had a lot of "cool" factor with users ("I liked that the auto-scrolling feature was responsive to how much pressure I applied", average response 6.4 and 6.6 in Rounds 1 and 2). Most users will not discover it on their own, but once users are aware of the feature, using pressure to increase speed is very natural ("It's just like talking louder!"). Some users are more successful than others in modulating the pressure from slow to fast.

Recommendations: Although it may be possible to further improve the algorithm so that all users can modulate the rate of scrolling across a wide range, the current algorithm seems acceptable. A hint about the pressure sensitivity ("Hold to keep scrolling – press harder or softer!") was added to the help panel, resulting in more users discovering the pressure sensitivity. Several improvements have already been made to the algorithm based on observed problems, particularly to limit the maximum rate of scrolling, as well as to start the scrolling at a fast rate if the user's initial pressure was already at a high value (instead of requiring further increase in pressure).

***Double-Tap Arrow to jump to Home / End of Document**:* Although many users liked the *idea* of this feature, a very serious problem of false recognition exists. Whenever the user pages up or down several times in succession, multiple taps of the arrow may be recognized as a double-tap. Thus the user always has to be careful to hit the arrow slowly when using the paging feature, resulting in decreased efficiency, as well as constant cognitive overhead from fear of making a mistake (and remembering to go slowly). I repeatedly observed users jumping to the beginning or end of the document by mistake when they were just trying to focus on going up or down a few pages.

Recommendation: *Do not implement any double-tapping feature on the arrows* because it interferes with Page Up / Page Down, and users will repeatedly invoke it when they do not want it. Instead, try a control key combination like Ctrl + Tap Arrow.

Double-Tap to Jump (main area)

While some users loved this feature, it has several usability problems. First, despite tweaks to the double-tap detection algorithm, the software could never reliably detect double taps from all users, nor could it reliable reject "false" double taps while users were just scrolling (Fig. 12). Every single user experienced at least one false recognition of a jump. The wide variety of usage styles of the strip makes this a difficult technical problem. Second, when users perform the double-tap, it is difficult to precisely or repeatedly tap on a particular location. Thus users would often have to double-tap several times to get to the desired spot. Some users didn't care about this, because they would just stroke the strip to adjust the scrolling after jumping. Third, almost all users had a tendency to look at the strip before or during the double-tap gesture, taking their eyes off the document. Fourth, when the jump occurs the screen changes suddenly and the user may not realize where they are (especially if the jump is triggered by mistake). Fifth, some users find the double-tap gesture physically difficult to articulate.

	"When I touched some part of the Scrolling Strip, it sometimes caused an action that I didn't intend."	Comments
Round 1	4.6	Users sometimes triggered double-tap by mistake.
Round 2	6.6	Implementation was changed to detect double-tap with more users. Instead it went off by accident far too frequently.
Round 3	2.8	Changed again. Few false positives, but users had trouble triggering double-tap when they wanted it.

Fig. 12. User responses were very sensitive to accidental activation of Jumping.

Finally, some users who accidentally triggered jumping more than once in their initial experience with the scrolling strip then exhibited a tendency to *refrain from making contact with the scrolling strip* when they were just reading, for example. This resulted in static load on the hand, fatigue, and discomfort. Some users became afraid to touch the strip except when necessary. This type of usage was not observed in Round 3, where accidental jumping occurred the least.

Several variants of the jump feature were tried to address the above problems:

Jump to Home or End only: The jump gesture was only recognized at the far ends of the strip. For users who liked jumping, they resented the removal of the ability to jump to the middle of the document; as one user put it, "the middle is where all the good stuff is – the top is just the title, the end is just the credits!" For users who had difficulty with the feature, imposing this constraint did not really seem to improve their experience. However, this version of the feature does greatly cut down on the number of false-positive recognitions that will occur, because the gesture is ignored on most of the strip.

Jump in 25% increments only: This feature jumps only to the 0%, 25%, 50%, 75%, and 100% positions in the document. This was similarly resented for limiting functionality, and did not help those who found the jumps confusing. Furthermore, users could get confused if they tapped twice, but the document did not move (because they had landed in the same 25% region again).

Jump with Animated Transitions: To help the user get a sense of where the document was moving, a 1/3 second animation was added. Some users preferred this, but others found the flow of text dizzying or disorienting. Overall it seemed to help a little bit.

Single tap to Jump: This makes the jump gesture easier to perform, but false recognition is all the more likely. Also, many users commented that it was *slightly* easier to make the gesture, but it wasn't a big difference.

Increased pressure to Jump: The user can jump by pressing harder. This was implemented but abandoned prior to user testing because it was observed that finger pressure (contact area) on the main area of the strip can vary quite a bit. Thus it did not seem to help make a more reliable gesture. It also seemed fatiguing and somewhat unnatural.

Feedback of finger position: In Round 1, users had commented that if on-screen feedback of their finger position were available, they (1) would not have to look at the strip itself, and (2) thought they might be able to jump more accurately. This feedback was added via a red rectangle seen in the Help Panel (Fig. 15). While users seemed appreciative of this added feedback, and did not find it distracting, it did not seem to improve user experience with the jumping feature.

Recommendations: While a powerful feature, the double-tap gesture on the main area of the strip is *very risky* to the overall user acceptance of the scrolling strip. Users become very confused and annoyed when jumping happens by mistake. If the feature is kept, *Jump to Home or End only*, plus *Jump with Animated Transitions* seems the least harmful variant. It is recommended to eliminate this function, turn it off by default, or provide similar functionality to this feature by another means (see "Absolute Mode" below). Of the other options that were tried, *Increased pressure to Jump* does not work very well at all, *Single tap to Jump* is definitely worse than double-tapping, and *Jump in 25% increments* does not help to improve the key problems with jumping.

Absolute Mode ("Rapid Scanning")

We explored the addition of an absolute mode, called rapid scanning, which provides behavior similar to dragging the handle of a traditional scroll bar. When the absolute mode is triggered, sliding one's finger along the main area of the strip moves the document to a corresponding position from the top to the bottom of the document. This differs from Jumping, described above, because the gesture is continuous rather than a "one-shot" gesture to move to a particular spot in the document. Fig. 14 summarizes questionnaire items related to absolute mode / rapid scanning.

Alt or Shift + Slide: In Round 3, holding either the Alt or the Shift key and sliding one's finger along the strip triggered rapid scanning mode. Breaking contact with the strip exited the rapid scanning mode.

This feature had a varied user response. Three users rated it highly (7, 7, 6) while the other two rated it very low (1, 2). The users who liked it appreciated the ability to get around quickly. Those who disliked it seemed to expect it to move the view relative to its current location, rather than with an absolute mapping. None of the users discovered this function on their own (it was not mentioned in the help panel). However, the feature will not be triggered by accident, so adding it does no harm to those who would prefer not to use it.

Recommendations: This feature adds some value for some users, but does little or no harm to those who would prefer not to use it. In essence its use is optional. Also, end rapid scanning mode if the user lifts off of the modifier key (rather than waiting until they also lift off of the strip itself). Finally, try changing the feature to instead provide a high-gain mode, rather than absolute motion, since users who disliked the feature seemed to expect this.

Dedicated "Sawtooth" Area *(Fig. 13)*: In this prototype, rapid scanning occurs in a separate area at the side of the scrolling strip. This area has a sawtooth edge to provide tactile feedback of the differing function. Four out of the five users liked the feature when it was presented in this manner. In Round 3, where users were presented with several physical layouts of the scrolling strip, several users picked this version as their favorite because of the "sawtooth feature." As one user put it, "that is kind of neat, you can pick between the two" modes of operation, without hitting any special key.

Recommendations: This version provided the best user experience with the rapid scanning feature. It is unclear if the new area at the right of the strip might confuse users during their initial experience, since this was not tested. This feature should also be tested with a high-gain mode instead of absolute motion, since some users again expected it to work this way.

Fig. 13. Scrolling strip with absolute function in the "sawtooth" area on the right side of the strip.

Double-Tap-And-Slide: Rapid scanning was tried in Round 1 as an extension of the jumping gesture. Tapping one extra time, and then leaving the finger in contact with the pad, triggered rapid scanning mode. Breaking contact ended it. Several users could not make this gesture at all. However, the gesture was not triggered by mistake. Some users could make the gesture but would accidentally exit the mode by lifting their finger.

Recommendation: Not recommended. If this feature is supported, instead use one of the other two methods described in this section.

Round 1: Dbl-Tap + slide	Round 3: Alt/Shift + slide	Round 3: "sawtooth" area	Question
5.25	4.6		The Rapid Scanning feature was useful to move around the document quickly.
3.0	3.0		The Rapid Scanning feature was too hard to use.
		6.4	Sliding in the "sawtooth" area on the right side of this scrolling strip was easy to use.
		2.8	I would prefer a scrolling strip WITHOUT this feature.
		5.0	I would frequently use the Rapid Scanning feature that I just tried.

Fig. 14. Summary of user responses to variants of Rapid Scanning.

Help Panel (Fig. 15)

A context-sensitive help feature was explored to help users get started with discovering and effectively using the scrolling strip. This "help panel" appears on the screen when the user touches the scrolling strip (that is, any exposed portion of the underlying touchpad). Relevant questionnaire items are summarized in Fig. 16.

In Round 1, the help panel disappeared immediately when the user broke contact with the strip, and the help panel contained only links which could bring up a new window with help information. Users did not know how to make the help stay up. Users were not sure how to activate the links, and thought the strip itself was used to select them. Only 1 user clicked on the link for help during their initial experience. In sum, this design was totally unsuccessful.

After Round 1, The panel was modified to remain visible for several seconds after the user let go of the strip (5 seconds in Round 2, extended to 10 seconds in Round 3), and to display a quick summary of the main features of the strip, without requiring the user to click on any link. The most recently activated feature was also highlighted in this help panel (several users commented that they liked this). An option to "Hide this window" was also added. Finally, the window itself was modified to be a moveable window with a close box, to give the user some control over its placement, and to quickly get rid of it if necessary (the window is not resizable, however).

After Round 1, every single user at least saw the help panel and realized what it was. Some users read or skimmed the information, but only a couple of users clicked on any of the links for more information.

Several users commented that the panel helped at first, but they would want to hide it later. The "Hide this window" option was successful at accomplishing this. However, 2 users did not realize how to get the help back after checking

this option (they did not read the hint, to "Hold still on the strip to get it back").

Round 2 included several users rated as "advanced" on the Windows screener and my observation was that the more advanced users seemed to benefit less from the help. Thus, the help feature may be inappropriate for products targeted to such users.

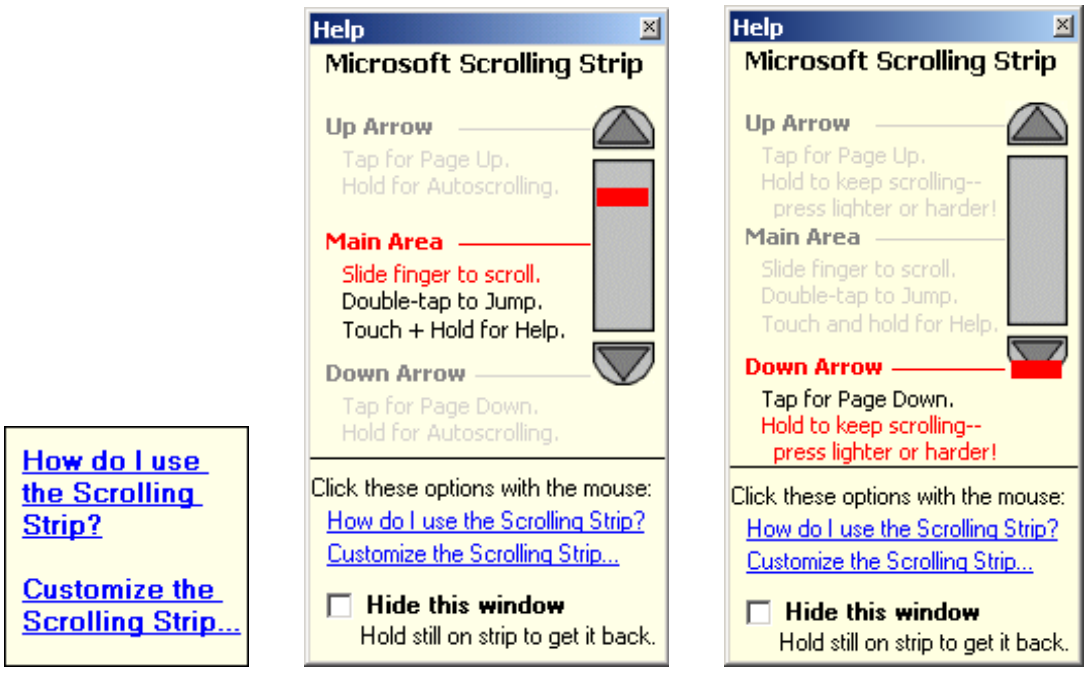

Fig. 15. ***Left****: The help panel as presented in Round 1.* ***Center****: The help panel as presented in Round 2. In this image, the user is touching the main area of the strip, so the "Slide finger to scroll" function is highlighted.* ***Right****: The help panel from Round 3; here the user has activated the autoscrolling function on the down arrow.*

Question	Rating 1-7	Comments
The Help for the scrolling strip assisted me in discovering how to use the strip effectively.	NA (Rd. 1) **4.6** (Rd. 2) **6.2** (Rd. 3)	The only changes to the help between rounds 2 and 3 were (a) 5 second time-out extended to 10 seconds; (b) slight rewording of some phrases. Round 3 had more intermediate users.
Based on my experience, the Help was "annoying" or "got in the way."	NA (Rd. 1) **2.6** (Rd. 2) **1.8** (Rd. 3)	Overall it was not perceived as bothersome. Users could see that there was an option to hide it, and appreciated this.
It was obvious to me how to use the Scrolling Strip.	**4.0** (Rd. 1) **6.4** (Rd. 2) **6.0** (Rd. 3)	Rounds that included the improved help feature were rated much better.
Overall, the Scrolling Strip was easy for me to use.	**5.8** (Rd. 1) **6.0** (Rd. 2) **7.0** (Rd. 3)	Obviously more than the help feature is involved here, but it did seem that it contributed to initial ease-of-use.

Fig. 16. Questionnaire items related to the help panel and ease-of-use.

Recommendations: The help panel as presented in Round 3 does seem to help many users get started with the strip. It may not be appropriate for advanced users. A remaining issue is that some users may not realize how to get the help panel back after checking "Hide this window." It should be possible to bring up the help panel through traditional means such as a taskbar icon or system control panel.

Other Features

Audio Feedback: The software supports a number of sounds which provide feedback or confirmation of functions. While some users liked audio feedback, the overall response was not promising. The prototype in Round 1 actually included the most sounds, many of which were turned off for Round 2, and only a few were provided in Round 3.

Users never had an initial experience with the software when no sound at all was present. It is possible that the sounds prevented the users from making certain types of errors, but this could not be observed.

Based on user comments, the most useful sounds seemed to be:

- Sounds when striking the up/down and left/right arrows (striking the main area of the strip is silent in the current prototype).
- Hitting the beginning/end or left/right edges of the document. Prevents errors from the user not realizing they have reached an edge of the document.

Round 1	Round 2	Round 3	Question
4.6	2.2		The Scrolling Strip was easier to use when the software made sounds.
3.8	5.4		The sounds that the program made while I was scrolling were annoying.
		1.2	The sounds that the program made while I was scrolling were helpful to me.

Fig. 17. Questionnaire items related to audio feedback.

Recommendations: Any sounds should be optional and probably off by default as well. A future study should include initial experience with totally silent operation.

Bookmarking: In Round 1, a bookmarking feature was implemented which allows the user to mark certain distinguished positions in a document and return to them easily. This appeared as part of the help panel, and suffered all the problems associated with the help panel design of Round 1.

Users were not sure of the purpose of bookmarks or how to operate the interface as presented in Fig. 18. The user can click on the Add Bookmark button, or click at any point along the arrow to jump to the corresponding point in the document. When the user adds a bookmark, this is indicated by a line across this arrow (Fig. 18, right). Users could return to an added

bookmark by clicking near this line. Users did not understand that this represented a bookmark, or that it was something they could click on.

Users furthermore felt that bookmarks would be hard to share with others, that they did not remember points of interest by their location (but rather by the content or keywords), and that they did not understand what would happen to bookmarks as they edited a document.

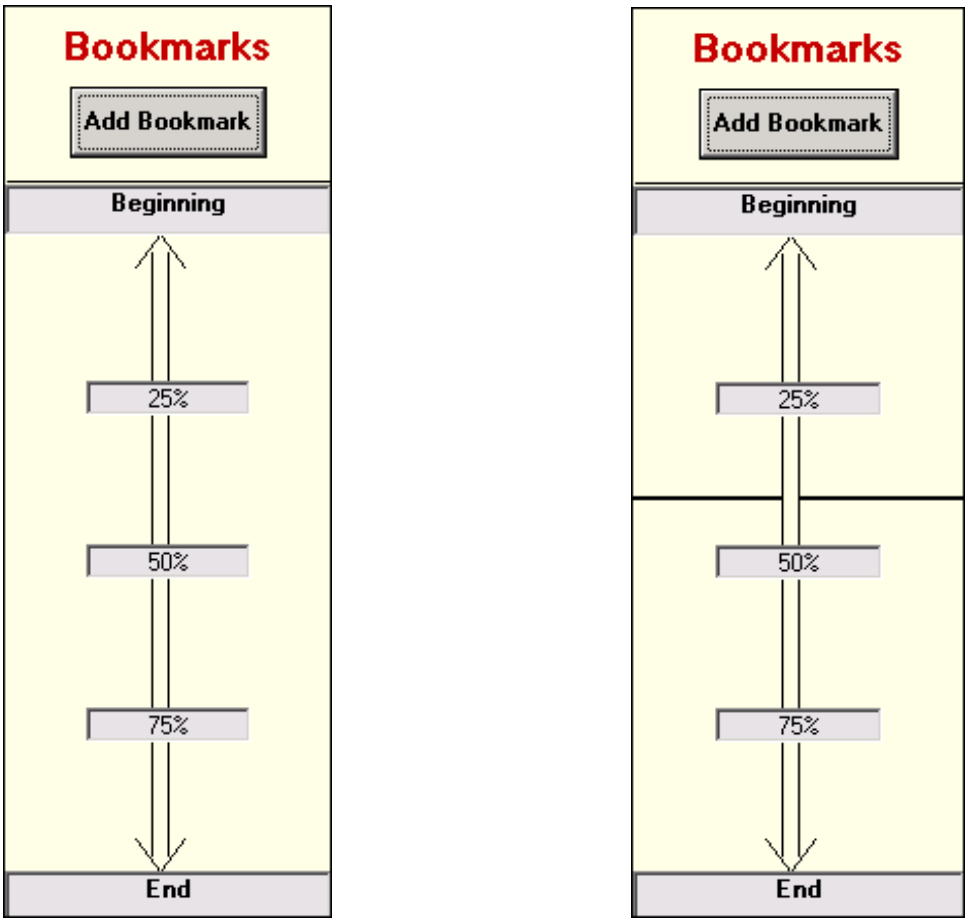

Fig. 18. Bookmarking panel. On the right, a single bookmark (horizontal black line) has been added.

Some users, however, did feel that bookmarks might be useful in long, frequently used documents.

Recommendations: As conceived in this prototype, bookmarks do not have much value for the end-user and the interface did not work at all. This feature, as proposed, should be abandoned.